SPRING WILDFLOWERS OF NORTHERN ARIZONA

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MUSEUM OF NORTHERN ARIZONA

SPRING WILDFLOWERS OF THE DESERT

by Arthur M. Phillips, III

Golden yellow Poppies, rich purple Scorpionweeds, royal blue Lupines, bright yellow Bladderpods, and a hundred other species with equally colorful names and flowers—this is the cast of characters in the Southwest's greatest natural drama, the springtime flowering of the desert.

Because popular publications usually focus on spring flowering in the deserts of southern Arizona and southern California, many people do not realize that northern Arizona often equals other parts of the state in the showiness of its spring wildflower displays. The Inner Gorge of the Grand Canyon and the Mohave Desert country of northwestern Arizona, for example, are often unsurpassed in the beauty and variety of flowers to be seen.

One of the best springs in northern Arizona in recent years was 1973—a year that will long be remembered for its wonderful displays of wildflowers in the desert and for the heavy snows it brought to the high country. The Grand Canyon that year was a colorful rock garden along the Colorado River, and the Mohave Desert in Lake Mead country put forth a display of grand proportions. Adding to the significance of that spring eleven years ago was the fact that it followed four years of drought that had produced springtimes with little or no showy flowering.

As anyone who has observed the variation in kinds and numbers of spring wildflowers from year to year suspects, the combination and timing of winter storms and temperature needed to bring forth quantities of flowers or to prevent their development until another year are rather intricate. Scientists have only scratched the surface in understanding these intricacies. While the ecology of desert spring wildflowers is a complex subject, its main points are well known and can be easily explained.

Actually, spring annuals are not adapted to desert conditions in the same sense as some of their neighbors, such as cacti and desert shrubs. They completely avoid extreme heat and lengthy drought by confining their growth to winter and remaining dormant as seeds during the summer and during dry winters. Perhaps their most remarkable adaptation is their capacity for prolonged seed dormancy, which

Grassleaf Peavine A. Phillips

Mexican Poppy A. Phillips

Bladderpod A. Clay

may last for many years until favorable conditions are met.

Rainfall, temperature, and daylength are the three most important factors in determining the extent of spring flowering. Of these, rainfall is certainly overriding; if rain is lacking or insufficient, no combination of other factors matters. Temperature is critical in that it must be neither too cold nor too warm for seeds to germinate and seedlings to grow. And daylength, which of course gradually increases through the winter but does not vary from year to year, is important along with temperature in triggering flowering.

Rainfall

Let us consider each of these factors in turn, then put them together as they would ideally occur to produce a good year for spring wildflowers in the deserts of northern Arizona. The amount and timing of rainfall is the first critical factor in stimulating germination. It may come as a surprise that the character of the flowering season in March and April is initially determined between late November and the end of December, for this is the time during which rain must fall in generous amounts for the greatest number and variety of seeds to germinate. Years in which the early winter is dry do not produce spring annuals in quantity, no matter how much rain has fallen in the previous autumn or in mid-to-late winter.

The amount of early winter rainfall is also critical. At least one-half inch to one inch must fall — preferably as a gentle, soaking rain over a period of twelve hours or so. To ensure that they germinate under conditions allowing them the best chance for survival, the seeds contain a water-soluble germination inhibitor that must be washed away before they can sprout. The amount of rain needed to dissolve away the inhibitor is also sufficient to assure that the soil will remain moist long enough for the seedlings to become established.

Although one rain is all that is needed to get things started, subsequent rains in early winter serve to greatly increase the number of individuals and the kinds of seedlings that appear. Each individual seed differs slightly from all others of its own species, as well as other species, in its requirements for germination. The longer the persistence of favorable moisture conditions, the better will be the response of annuals. Never do all the seeds in the soil germinate. This can be shown by taking samples of desert soil into the laboratory and subjecting them to different combinations of watering and temperature. Each combination produces different seedlings, with the full potential of any sample never being reached. Thus do these tiny plants protect themselves against catastrophe; some always remain dormant in case a seemingly promising boom year in December turns into a bust in February.

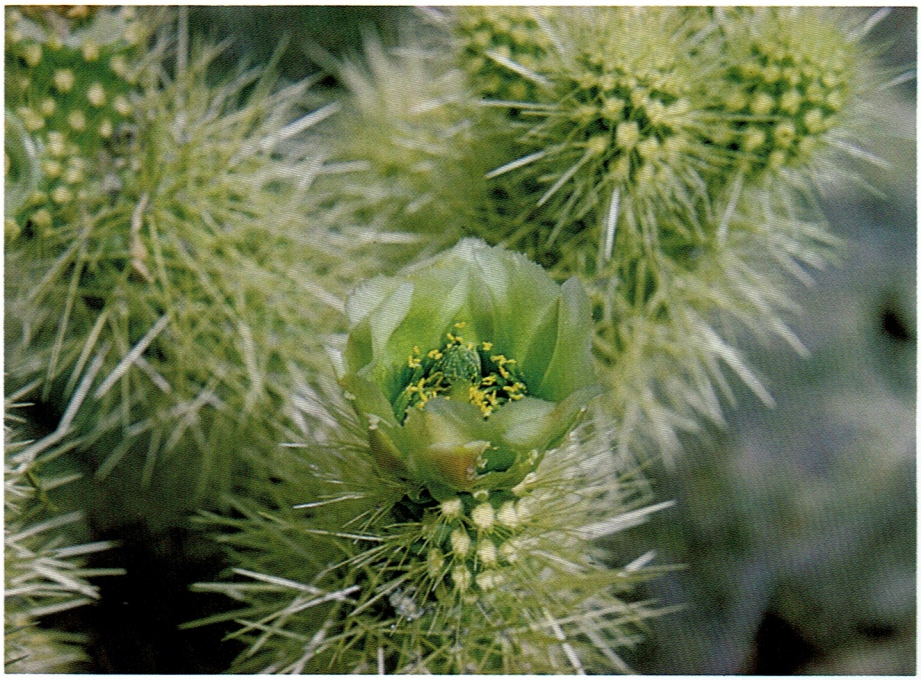
Steady, regularly spaced rains in early winter result in the best germination although the first good rain usually stimulates the greatest number of seeds to sprout, with fewer seedlings joining in with later rains. As the weeks progress into January, the ground becomes a carpet of green. Once germinated, the plants put out a few leaves and become more or less dormant; flowering is still some weeks off. By mid-to-late January, very little new germination occurs. This seems to be the case regardless of how much rain has fallen or how many seeds have germinated earlier. Thus, years in which early winter rainfall is lacking will not be followed by good flowering of annuals in spring — even if rainfall is copious in late winter.

Temperature

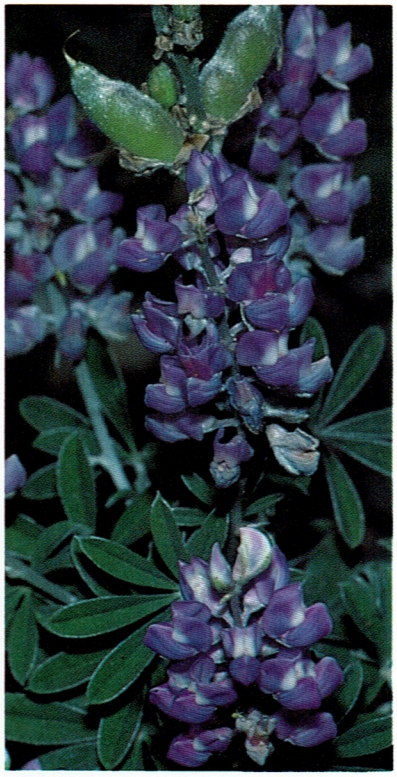
The role of temperature in the flowering of spring annuals is also critical, and it is closely tied to rainfall. After the first adequate rain of the season, the soil should remain wet for a week or two, and it is during this time that most germination occurs. The high and low temperatures that prevail are critically important in determining how many seeds germinate. Each species has its own rather narrow temperature tolerance limits for germinating, and seeds will not grow in quantity if these limits are exceeded in either direction.

Thus, seeds of winter germinating species never germinate in summer, even if generous rains occur, because temperatures in the desert exceed their maximum tolerance level. As temperatures gradually decrease during the fall, the potential for germination increases. By mid-November, the temperature range is low enough to be within the limits of many winter germinating species, and the seasonal storm patterns have shifted southward, giving a potential for adequate rainfall. The optimum temperature range for most species varies from lows of freezing to highs of about 65° F. Temperatures much below freezing inhibit germination in most species, and this is the main reason for decreased germination in midwinter, regardless of rainfall.

Once they have germinated, seedlings remain dormant while temperatures are low, but they are



Teddy Bear Cholla A. Phillips



Lupine J. Richardson

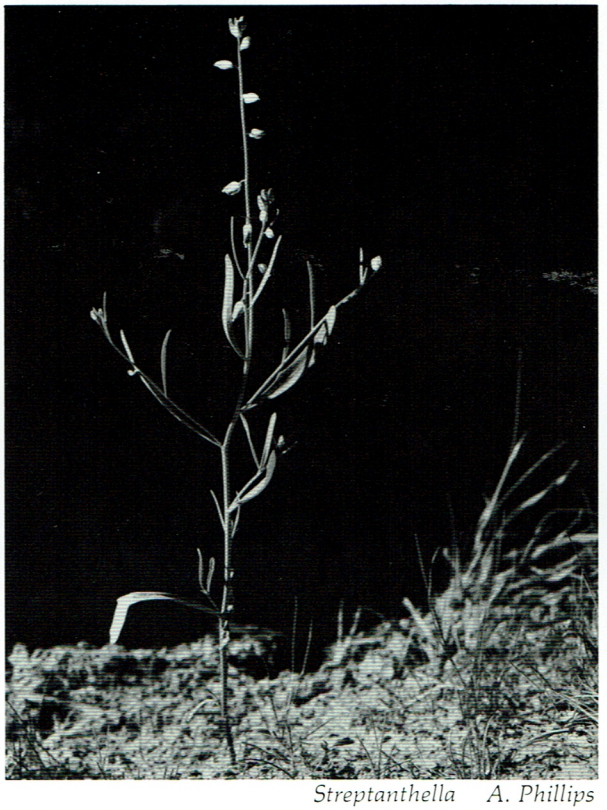
Rainfall, temperature, and daylength are the three most important factors in determining the extent of spring flowering.

Grand Canyon Scorpionweed A. Phillips

Twining Snapdragon J. Richardson

Utah Penstemon M. Jefferson

Sacred Datura J. Richardson



Streptanthella A. Phillips

Palmer Beardtongue A. Phillips

not killed by sub-freezing cold. Growth, if any, is very slow, and there is no sign of reproductive growth. February is the turning point. Depending on elevation, both maximum and minimum temperatures begin to rise to highs of about 75°F. and lows of about 50°F., stimulating the rapid growth that culminates in flowering a few weeks later.

Perhaps the second most critical period in determining whether flowering displays will be extensive occurs in later winter as temperatures begin to warm. Even if all has gone well before, the period leading into flowering must be mild and moist for optimum flowering. If February and March temperatures rise abruptly, plants will dry out before they have a chance to reach their full flowering potential. While most will live long enough to produce at least a few flowers and seeds, the flowering is premature, reduced, and foreshortened. At the opposite extreme, if late winter temperatures remain too low for the rapid growth period to occur, plants will remain small and nonreproductive later than normal. When it finally warms up in April, it usually does so suddenly — again resulting in rapid, reduced flowering and death of the plants before their full potential is met.

Daylength

Daylength is the only element affecting spring flowering that is consistent from year to year. It is closely allied with temperature. During the short daylight period of early winter, the year's lowest average temperatures are reached, and the warmer part of the day is shorter — with less sunlight available for photosynthesis. During the rapid growth and reproductive stage of late winter, days are considerably longer, shifting the emphasis toward the maximum temperature and providing a longer photosynthetic period.

These three factors (along with many others such as the presence of herbivores, wind, soil type, and seed reserves) act together over a period of several months to bring about the germination, growth, and flowering of spring annuals in the desert. The year-to-year variability of flowering — in terms of amount, timing, species makeup, and plant size — is testimony to the variability of interacting processes and to the great flexibility of these tiny desert dwellers.

Once they are established, a large proportion of seedlings progress to maturity regardless of how dry the following winter months may be. Moisture stress is the main cause of the mortality that does occur, but it usually does not become critical until coupled with increasing temperatures as spring approaches.

Desert annuals have an amazing ability to vary their size and number of flowers in response to moisture availability. During the cold midwinter, they remain small and vegetative, without any sign of flowering. As the late winter warming begins, their growth is dependent upon the amount of soil moisture available. If moisture is plentiful, and rainfall continues, plants will enlarge considerably — growing many branches, each of which produces an abundance of flowers. The combination of mild temperatures, longer days, and continuously damp soil from late winter well into spring is needed to trigger the large, showy displays of spring wildflowers everyone pictures as characteristic of the desert in spring.

At the opposite extreme, if warm temperatures arrive when the soil is dry and rainfall is lacking, plants enter their growth period under conditions of moisture stress. Some do not survive, but those that do live cope with stress by putting their energy into flowering instead of growth. They may increase in size very little from their dormant winter seedling stage, producing one or two flowers, always of normal size, that hide the tiny plant beneath. Except for the flowers, which do not vary in size, shape, or color from dry years to wet, the plants growing under the two extremes would hardly be recognizable as the same species.

The desert areas of northwestern Arizona, including the Inner Gorge of the Grand Canyon, are within the eastern part of the Mohave Desert — an area extending westward through southern Nevada and interior southern California. A hot desert receiving its scanty rainfall mainly in the winter, the Mohave supports the greatest variety of spring annuals of any of our southwestern deserts. The potential for a magnificent display of desert wildflowers, represented by billions of tiny seeds, is present every year, but the vagaries of the desert climate rarely provide the right combination of circumstances. Some years, the seeds fail to germinate; in others, they sprout but fail to flourish, while a good spring display is a relatively rare occurrence.

A good year may occur once or twice in five springs. A noteworthy display may develop only once in ten years, and an outstanding display may happen once in a human lifetime. Desert spring annuals and their tiny seeds lying dormant in the desert soil hold great promise that is only rarely fulfilled. They are truly more patient than those of us who spend long winters in hope!

Crimson Monkeyflower J. Richardson

Apache-plume A. Phillips

Creosotebush J. Richardson

SPRING WILDFLOWERS IN THE GRAND CANYON

by Arthur M. and Barbara G. Phillips

The spring wildflowers of the Grand Canyon, and particularly those of the Inner Canyon, can be a colorful treat for those who hike the trails or run the Colorado River in April and May. For the backpacker, the Tonto Plateau often provides an unexpected display as the otherwise rather monotonous vegetation comes alive, the landscape transformed by such spring flowers as Weakstem Mariposa Lily, Scorpionweed, Indian Paintbrush, and Beardtongue, among many others.

For those fortunate enough to take a springtime raft trip, the desert slopes of the Inner Gorge and the sand dunes along the river are home to many species of annuals and colorful cacti. It is a shame that most people taking river trips do so in summer when intense heat and drought have long since dried up the spring flowers and driven the shrubs and cacti to dormancy.

The Grand Canyon is critically situated in an area where three of the four major deserts of the Southwest meet. To the north (in northern Arizona, Utah, and Nevada) is the winter cold, high elevation Great Basin Desert. To the west of the Grand Canyon (from the Grand Wash Cliffs across southern Nevada and into interior southern California) lies the Mohave Desert, a hot desert region rich in annual plant species and receiving its rainfall mainly in winter. To the southwest (along the lower Colorado River, in southern Arizona and adjacent Mexico) is the Sonoran Desert, overall the richest of the North American deserts because it has both winter and summer rainy seasons.

Influenced by all three deserts, Inner Canyon vegetation has developed in response to elevation (determining rainfall and temperature) and distance from the main part of each desert area. The desert vegetation of the Inner Gorge shows the influence of the Colorado River as a narrow corridor along which Mohave Desert, and some Sonoran Desert, species have migrated upstream and are found far to the east of their centers of distribution west and south of the Grand Canyon.

Climatically, the Inner Gorge is indeed a hot desert with torrid, dry summers and mild, sometimes moist winters. Such conditions are ideal for Mohave Desert plants but are too hot and dry for those of the Great Basin Desert or woodlands. Consequently, the number of different kinds of plants found in desert habitats of the Inner Gorge is paradoxically greatest at the extreme western end of the canyon, near the Grand Wash Cliffs. While this is the lowest, hottest, and driest part of the river corridor, it is also closest to the main part of the Mohave Desert, explaining the richness of its flora.

In Marble Canyon, over 250 river miles from the Grand Wash Cliffs, the number of Mohave Desert species is rather small. The annuals and the Beavertail Cactus are the first to appear. A few miles above Saddle Canyon is the first Brittlebush, its large, yellow flowers opening in April. A good example of a Sonoran Desert species, Brittlebush is present throughout the Inner Gorge below this point. Plants typical of the Great Basin Desert, such as Sagebrush, are not found in the Grand Canyon; even in Marble Canyon, the summers are too hot and dry for them to survive.

A number of plants flower on the dunes and cobble beaches of Marble Canyon in April. Among them are many annuals, including Scorpionweed, Hiddenflower, White Evening Primrose, and Streptanthella, a tiny, white mustard found in abundance

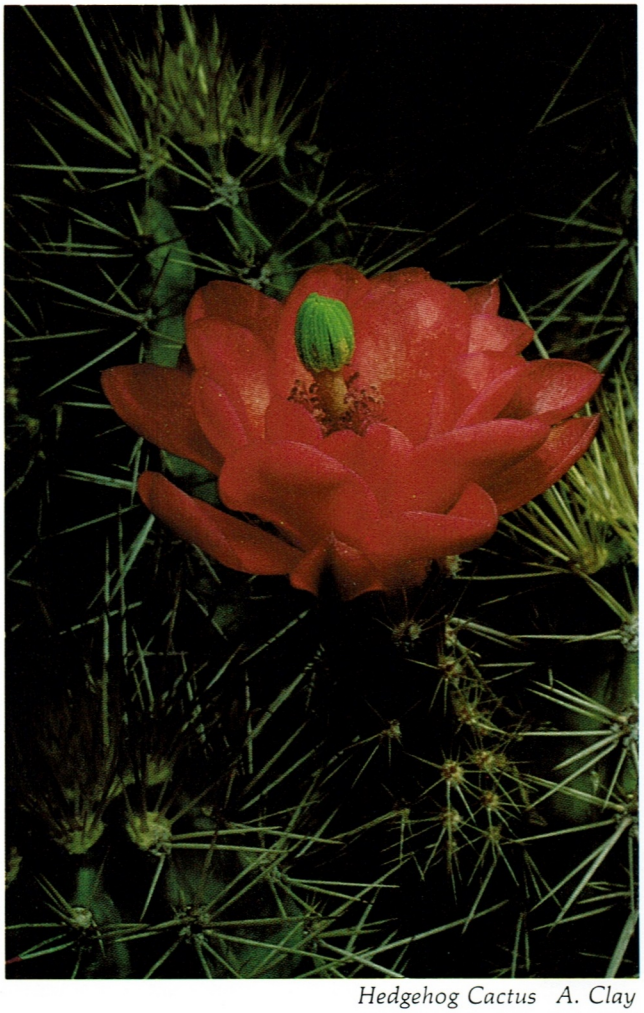
Brittlebush and Mormon Tea A. Phillips

Grizzly Bear Cactus M. Jefferson

California Barrel Cactus J. Richardson

Desert Dandelion A. Phillips

"Fairy Rings" of Desert Dandelion A. Phillips



Hedgehog Cactus A. Clay

The Grand Canyon is situated in an area where three of the four major deserts of the Southwest meet— the Great Basin, the Mohave, and the Sonoran.

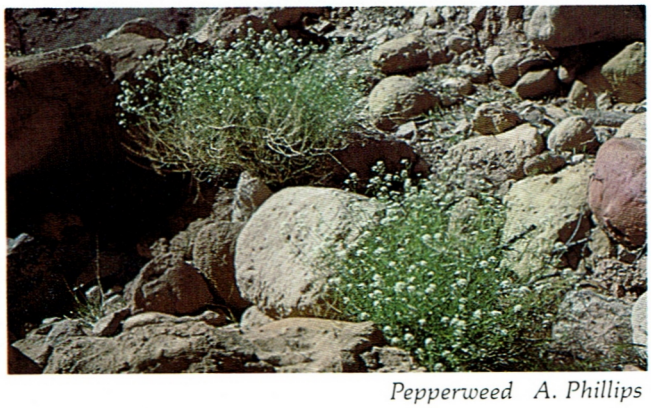
that is just coming into flower in this area. The cobble bench, which is slightly higher and more stabilized than the loose sand of the beach, supports large, showy plants of Desert Pepperweed, a shrubby mustard covered with tiny, white flowers; Apache-plume, a larger, white-flowered shrub; and Amsonia, an herb with rich, blue, star-shaped flowers. The cacti are just budding and will not flower for several weeks. Small trees of Western Redbud flower in April, their purplish-red flowers contrasting with the red-orange canyon walls.

A little past the mouth of the Little Colorado River, the Colorado turns rather suddenly into the Grand Canyon proper. The steep, narrow walls of Marble Canyon are left behind, and the canyon widens dramatically as the Desert View tower on the South Rim comes into view. "Furnace Flats" they call this widest part of the canyon in summer because it is baked in hot sun with very little shade, but in April it could be referred to as "Wildflower Heaven"

Helleborine Orchid A. Phillips

Western Redbud J. Richardson

Indian Paintbrush E. Balzer



Pepperweed A. Phillips

White Evening Primrose A. Phillips

since the gentle red slopes of Dox Formation and the broad beaches along the river are covered with spring annuals.

In April after a wet winter, the slopes are covered with acres of yellow, formed by tens of thousands of Desert Dandelion plants, the patches so dense the individual plants cannot be seen from any distance. One spring, river runners noticed something unusual just above Unkar Rapids. Instead of indistinct patches, the Desert Dandelions were growing in rings about ten feet in diameter, their centers free of plants. Upon close inspection, they found that the rings surrounded inactive ant hills. The centers were the cleared areas around the openings, and the yellow rings were where concentrations of seeds were actively or accidentally placed by the ants in the midden or refuse area surrounding the colony. The effect was striking, and later reports indicated that the "fairy rings" could be seen from as far away as the South Rim.

Below Unkar Delta, the canyon narrows into the Granite Gorge of black Early Precambrian schist, among the oldest rocks exposed on Earth. The steep walls have little soil, but Beavertail and Hedgehog cacti cling tenaciously to the walls. In April, both are in full splendor with large, pink flowers in this part of the canyon. Brittlebushes, scattered here and there, are now in full flower. The tiny Streptanthella that was just starting to flower in Marble Canyon is in full flower here and has been for a while. Its first flowers have now gone to fruit. Winters are warmer since the elevation is over five hundred feet lower here than at Lees Ferry.

From Phantom Ranch, two major trails lead to the Tonto Plateau. The wildflowers along the steep trails are magnificent. There are four or five different species of Scorpionweed; Mohave Asters with as many as fifty large, light-blue to purple flowers; Narrowleaf Yucca with its tall stalks containing many white flowers; the large, yellow, daisylike flowers of Goldenweed; and the tiny, purple flowers of Perennial Rockcress and Purple Bladderpod.

The comparative flatness of the Tonto brings a striking change in the vegetation. Brittlebush, abundant to the top of the Inner Gorge slopes, is abruptly replaced by Blackbrush that forms nearly pure stands of evenly-spaced shrubs on the plateau. Blackbrush is transitional between the Mohave and Great Basin deserts and is one of only a handful of species that they have in common. Since the Tonto lacks many other species typical of both deserts, it is difficult to categorize as belonging to either.

The wildflowers of the Tonto are also an interesting mixture. Most of the spring annuals are from the Mohave. The spring-flowering shrubs (notably the showy Purple Sage, a member of the mint family with striking blue and purple flowers) are mostly of Great Basin affinity. Adding to the melting pot nature of Tonto Plateau wildflowers are the perennial herbs, most of which originate in the woodland above.

A few miles below Phantom Ranch, the canyon opens into a large amphitheater on the north side, just upstream from Shinumo Creek. Its slopes are nearly solid yellow in April with the most spectacular display of Brittlebush to be seen anywhere in the Grand Canyon.

In the lower Grand Canyon, there is an increase in the number of springs and seeps in the canyon walls and up side streams. While varying in size and water flow, the seeps have a surprisingly uniform array of species. Maidenhair Fern, Crimson Monkeyflower, Golden Columbine, and Helleborine Orchid are the most common plants, and some of the larger springs are shaded by water-dependent trees such as Cottonwood, Velvet Ash, Birch-leaf Buckthorn, Netleaf Hackberry, and Western Redbud. The latter two are common on the dry, shaded slope of Marble Canyon, but in the lower part of the canyon, they cannot survive without supplemental moisture from seeps and springs.

The Mohave and Sonoran desert origins of the Inner Gorge flora are more evident as more and more hot desert plants are encountered until they finally become dominant in the lower canyon. California Barrel Cactus, which occurs in limited numbers far upstream, becomes abundant on the steep, rocky slopes of the lower canyon. White Bursage first appears at Tapeats Creek; Ocotillo is next, appearing just above the mouth of Havasu Creek, with its green wandlike stems tipped with flares of bright red flowers; and Creosotebush finally enters just below National Canyon. These three are dominant species through the remainder of the Grand Canyon although the number of species of spring annuals increases as well.

In the western part of the canyon, the little Streptanthella, which is present on nearly every beach, has finished flowering by late April and is completely in fruit. The river drops nearly two thousand feet in elevation between Lees Ferry and Lake Mead, and the spring flowering is considerably more advanced in the lower canyon. The Grand Canyon, with its great diversity of elevations, habitats, and soil types, clearly ranks as one of the prime spots in the Southwest for enjoying spring wildflowers.

THREATENED AND ENDANGERED SPRING WILDFLOWERS

by Barbara G. and Arthur M. Phillips

In January, the West Fork of Oak Creek Canyon can be a winter fairyland as myriads of delicate ice crystals form at the contact of ice and water and frozen waterfalls cascade off the cliffs. Certain areas in the canyon retain deep snow even when most of the ground is bare between storms. Sunlight evidently never hits the canyon floor in these areas because of shading by cliffs on the south side of the canyon. These microenvironmental conditions have a definite impact on the plants that appear later in the year in these habitats.

Botanists from the Museum of Northern Arizona have been traveling throughout Arizona for the past six years assessing the status of plants for listing as Federally Threatened or Endangered. One of the species under consideration as a Threatened species, the Arizona Bugbane, grows in West Fork and in several places in Oak Creek Canyon, but until recently, little was known about its distribution and ecology.

Riparian habitats are especially vulnerable to threats. As many biologists have noted, riparian habitats associated with free flowing aquatic systems support some of the most diverse species assemblages (both plant and animal) and highest plant population densities in the continental United States, but only thirty percent of the original area of riparian ecosystems of the United States remains uncleared. In an arid state like Arizona, probably less than 0.4 percent of the total land area has riparian vegetation.

Many of the springs in Arizona have been "boxed" (contained) for use in fire prevention or for livestock; others have been drained. This has resulted in the loss of much of the potential habitat for riparian species—especially in the mountains of southern Arizona, such as the Santa Ritas, Huachucas, and Chiricahuas.

Protection of endangered species is often a major issue in the not-always-compatible struggle between developing our natural resources and protecting our natural environment. Species extinctions have increased dramatically as development has accelerated, especially in the tropical parts of the world. In the United States, the Endangered Species Act, administered by the U.S. Fish and Wildlife Service, began protecting plants from commercial exploitation in 1973. Since 1978, habitat that is critical to the survival of plants listed as endangered and threatened has also become protected.

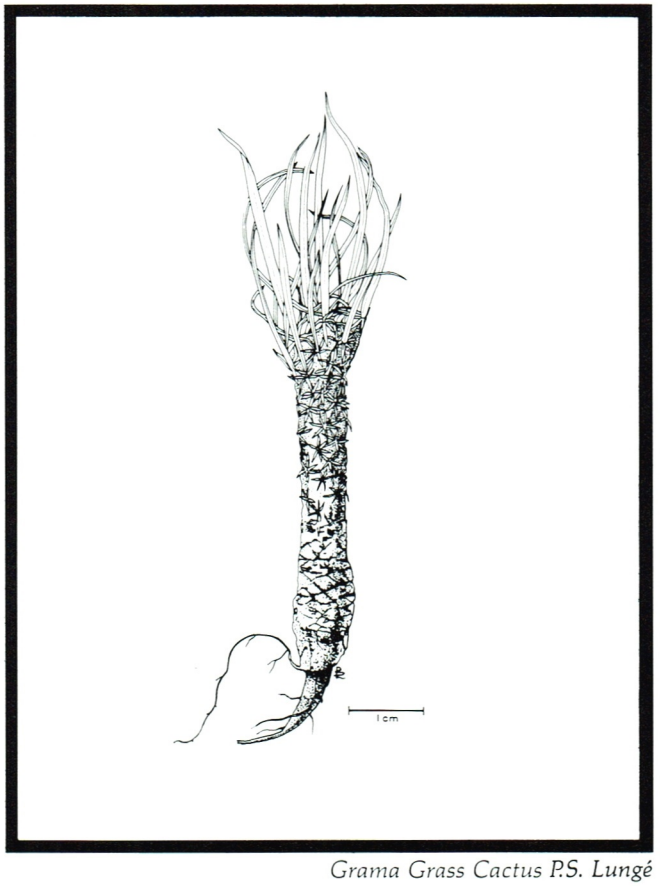
Another fragile habitat is the alpine ecosystem on the San Francisco Peaks. The San Francisco Peaks Groundsel, endemic to the volcanic mountains that rise above Flagstaff, was officially listed as a threatened species on December 22, 1983. Since it was threatened by human off-trail trampling, protection of this species will help protect the entire alpine ecosystem of which it is a component.

The other three federally listed plants found north of the Mogollon Rim, all listed as endangered, are small cacti of the genus *Pediocactus*. Collection pressure, or "taking," is a real threat to plants that are very attractive or highly desirable as ornamentals. Small cacti are especially vulnerable; cactus collectors (private individuals and commercial dealers) have reduced populations of one small cactus in New Mexico from over one hundred thousand to less than three thousand plants in twenty years.

The Navajo Plains Cactus and Brady Plains Cactus were discovered and named in the mid-1950s. Since they were unusual, distinctive species, interest in them developed immediately, and collection has become a major threat to both. These species are difficult to grow on their own roots because they are susceptible to root-rot, so a constant drain on the

Arizona Bugbane **M. Sharp**

San Francisco Peaks Groundsel **M. Sharp**



Grama Grass Cactus **P.S. Lungé**

Desert Columbine **M. Sharp**

Botanists from the Museum of Northern Arizona have been traveling throughout Arizona for the past six years assessing the status of plants for listing as Federally Threatened or Endangered. The protection of endangered species is a major issue in the not-always-compatible struggle between developing our natural resources and preserving our natural environment.

Navajo Plains Cactus A. Phillips

wild populations probably occurs to replace plants that have died in cultivation, as well as those taken for new collections. Mining, grazing, road construction, and housing developments have destroyed some of the habitat of these species so that today the remaining populations are threatened by *any* use of the habitat as well as collection pressure.

Wild-collected cactus seed is a big business for the wholesale propagating nurseries. However, the collection of seed from cacti that do not maintain large seed banks in the soil can do considerable damage to the wild populations. Also, direct damage to the plant's growing tip from the incorrect removal of seeds may prevent the plant from flowering or fruiting again.

The proliferation of roads into the backcountry has provided access to formerly remote sites, making some species more vulnerable to collection. Some rare species have also been destroyed by construction of major highways such as Interstate 40. The recent growth of southwestern cities and towns and the consequent population expansion into the surrounding countryside destroys the habitats of many plants. Although this is a more serious problem around such urban areas as Tucson and Phoenix, the growth of Flagstaff has removed habitat of two species considered for listing.

One of these, the Desert Columbine, is a beautiful, delicate species with yellow petals and red spurs. It grows on rocky limestone bedrock such as the outcrops in the vicinity of the south campus of Northern Arizona University. These sites are now occupied by buildings such as Northern Arizona University's Skydome. Fortunately, many more populations of the species have been found from a number of widely scattered locations, so the Desert Columbine is no longer considered threatened. It is noted for both its longevity and an enormous root system so that it becomes a successful plant once established — taking advantage of all cracks, ledges, and soil-filled potholes in the limestone bedrock.

Some species take a bit more detective work to find. Botanists at the Museum of Northern Arizona searched for a tiny, annual, Evening Primrose, *Camissonia exilis*, without success for four years on the Arizona Strip north of the Grand Canyon. Other botanists for the Bureau of Land Management were equally stymied in their attempts to locate the type locality, a "gypsum-covered flat, near Cottonwood Spring, east base of the Virgin Mountains."

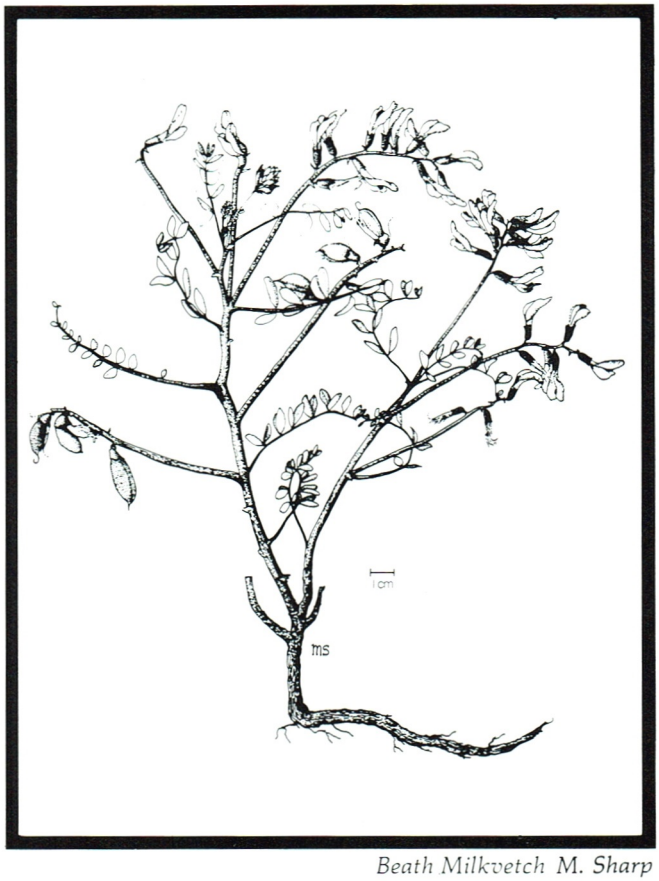
Noted prominently on a map was Cottonwood Spring near Jacob's Well with gypsum areas nearby. The botanists scoured the gray "badland" hills of sunbaked clay and gypsum, battling black gnats by covering every inch of their bodies with clothing or insect repellent despite the ninety degree heat. One night, they stopped four different places only to be overwhelmed again and again. They finally found relief only because these insects retire at sunset, not because of any unique feature of their last campsite.

It was while sitting in the truck to avoid the pesky insects that the botanists poured over topographic maps and the two articles mentioning the collection localities. Two puzzling facts became evident: the elevation of the site being searched was one thousand feet too high (3500 feet in the literature), and the original 1962 article described the type collection in 1941 as from "1/4 mile north of Jacob's Ranch on road to Northwater Spring." By the time the second article was written in 1967, this was changed to "Cottonwood Spring, east base of the Virgin Mountains." They began to suspect that there must be another Cottonwood Spring at a lower elevation, somewhere near a Northwater Spring.

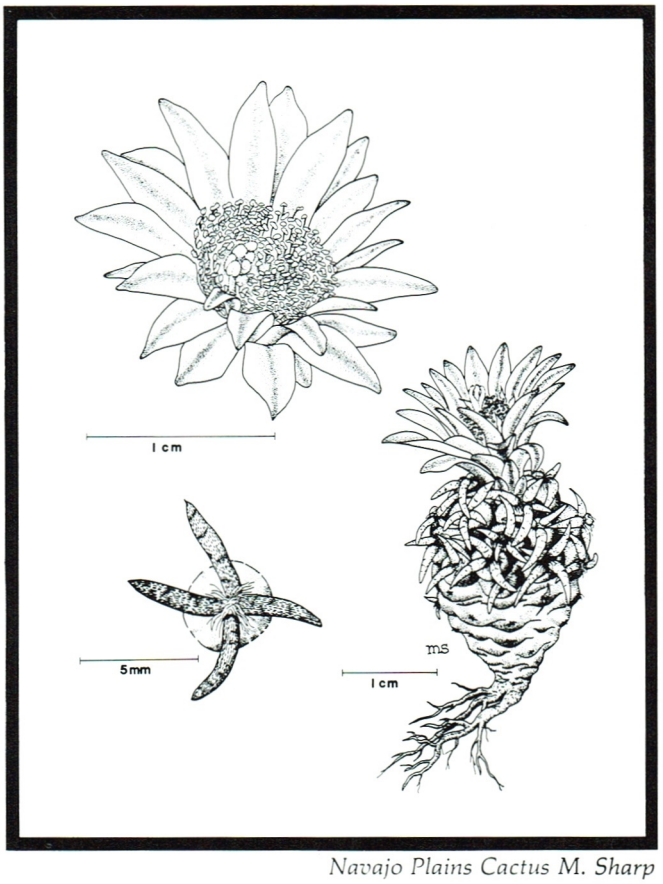
Looking at some maps dating from the 1940s, the botanists found Northwater Spring near a Jacob's Ranch twenty-five miles to the south. The elevation was correct, and although there was no Cottonwood Spring on the map, they felt confident about the location.

The second Jacob's Ranch had many large, old cottonwood trees, which may have given the place its local name forty years ago. Finally, after searching several potential gypsum-clay habitats (although Northwater Spring was on the map, it was difficult to determine which ranch road led to it), MNA botanists located the site. Unfortunately, the little Evening Primrose was not found, but the botanists were certain it was the right location. All the data fit, even the associated species (which were different from those on the nongypsum soil). A dry spring had probably prevented the germination of the tiny, annual plant.

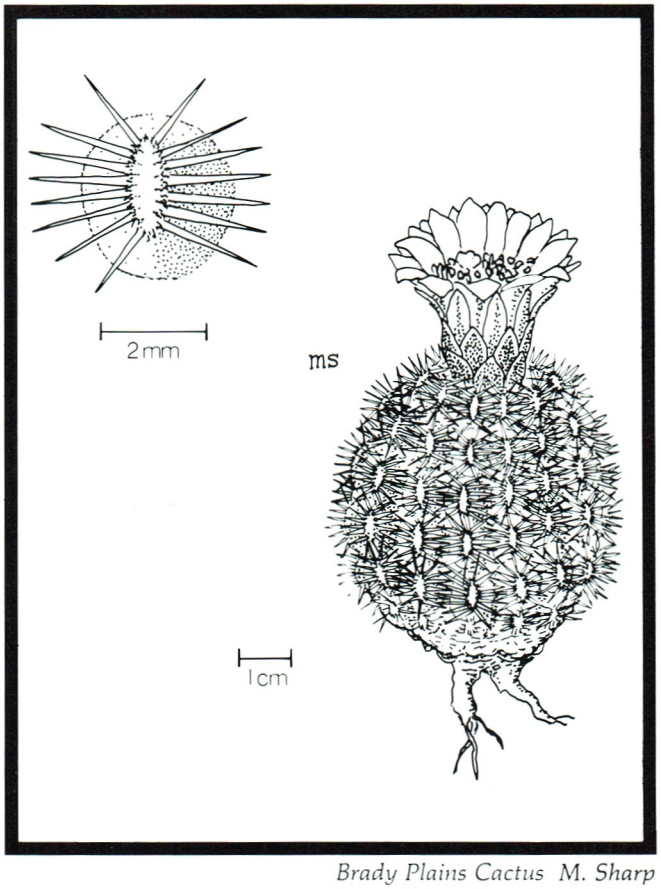
In 1982 the botanists set off on their annual "Strip Trip" with high expectations since it had been a wet spring. They were not disappointed. The elusive Evening Primrose was there in abundance on the "correct" gypsum flat. Many years of searching and sleuthing were rewarded finally, giving the botanists a great deal of satisfaction and a feeling of double triumph — for having at long last solved the puzzle and for the little plants, which were still there forty years later, just waiting for someone to find them.



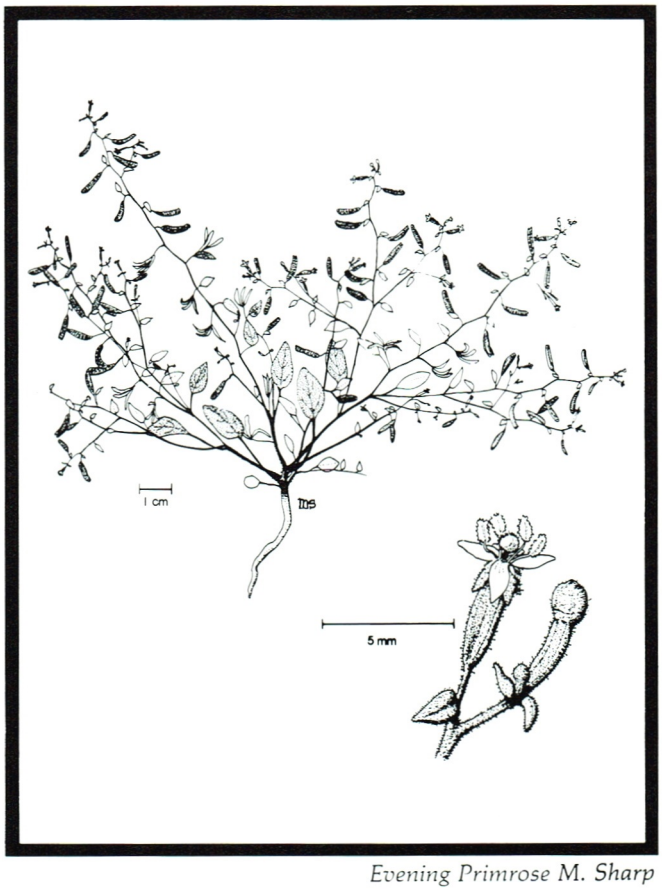
Beath Milkvetch M. Sharp



Navajo Plains Cactus M. Sharp



Brady Plains Cactus M. Sharp



Evening Primrose M. Sharp

Other species are easy to locate, but assessment of the viability of the populations may require persistence.

Beath Milkvetch is an interesting legume first discovered by Professor O.A. Beath two miles south of Cameron while he was on a field trip in connection with his work on seleniferous plants. Noteworthy mainly for its strong, malodorous smell, this species was thought to be very rare and local in occurrence.

Very few plants, mainly roadside, were noted along Highways 89 and 164 in 1980 and 1981. In addition, imagine the botanists' dismay when they found what had been a fairly sizeable population west of Cameron in April 1981, but every plant was dead! Sadly, they collected some specimens and took them to Dr. R.D. Gilbertson of the Department of Plant Pathology at the University of Arizona. He identified the pathogen as charcoal rot, a fungus that probably invaded plants stressed by other factors, such as late frost or moisture stress. Dr. Gilbertson was interested in the phenomenon because it had never been reported from Milkvetch before.

Encouraged by the thought that this fungus alone had not caused the deaths of all the plants in the population, the botanists again searched for Beath Milkvetch in 1982. Following the wet winter, the plants were numerous at the known population sites. In fact, at the site west of Cameron where all plants were dead in 1981, the lilac and white flowers carpeted acres in all directions. Quickly breaking off a stem to verify the identity, they filled out their data sheets and photographed the beautiful but terrible-smelling plants.

Although Beath Milkvetch grows on rangeland subjected to heavy livestock grazing, its biochemical makeup protects it from being eaten. Other plants, however, may be adversely affected by grazing or by trampling, especially during the wet seasons. Indirect actions, such as the removal of associated species and the dislodgment of rocks, can also result in the loss of protective cover, compaction of soil, and increased erosion.

The tiny Grama Grass Cactus formerly was found over the extensive grassland of northeastern Arizona and western and central New Mexico, but intensive use of the range has drastically altered its habitat. It is a small, cylindrical cactus two to three inches high and about an inch in diameter. The main spines are white, paperlike, and flexible, very similar in appearance to the dry leaves of the bunch grasses with which the plants are strongly associated. This camouflage protects the cacti from the sun and from herbivores such as rabbits and rodents. The plants are very difficult to locate in healthy grass clumps, so they are also protected from human collection pressure. However, where the grasses are closely cropped, the cactus fails to reproduce and disappears from the area.

The small Navajo and Brady Plains cacti mentioned earlier are emergent only during a short wet period in the spring. After flowering and fruiting, they contract under the soil surface for the remainder of the year. Trampling by grazing livestock is, therefore, most detrimental during the season when they are emerged and reproductive. The muddy soil that accompanies the rain also enables the animals' hooves to sink further into the ground — increasing the destruction.

Livestock grazing also threatens some populations of Arizona Bugbane. In addition, logging, which opens up the forest canopy, has destroyed the habitat where the species was first collected. Since the Research Natural Area of West Fork, where such activities are prohibited, provides the most protected habitat for the species, MNA botanists returned in late June to assess the extent of the populations in that spectacular canyon.

It was remarkably easy to spot the plants with their tall plumes of white flowers waving above the lush green foliage of the herbs and shrubs like Red Osier Dogwood and Wax Currant. As expected, riparian trees such as Arizona Alder, Arizona Walnut, Big-toothed Maple, and Douglas Fir (growing at low elevations because of the shade and water) provided the canopy above the sites.

The most amazing thing about the populations was their locations. As more populations were discovered, it soon became possible to predict exactly where each would occur. The Arizona Bugbanes in West Fork grew only at the base of the cliffs where the seeps had formed such beautiful frozen waterfalls in the winter and on the shaded canyon floors where the snow had been so deep!

Beath Milkvetch B. Phillips

San Francisco Peaks Groundsel A. Phillips

Arizona Bugbane B. Phillips

SPRING WILDFLOWERS IN THE FLAGSTAFF AREA

by Barbara G. Phillips

Each year spring seems to come with such difficulty to the high plateau country of northern Arizona that many people flee impatiently to the desert in their search for spring wildflowers. But a great diversity of spring wildflowers *can* be found in the Flagstaff area with a little effort, an awareness of where to look, and patience. The beauty of spring wildflowers here, however, comes not in a big splash of color but in small wonders spread over the span of several months.

Although appearing very uniform from a distance, the Ponderosa Pine forest around Flagstaff contains several distinctive habitats. The pine forest itself, the meadows, the mesas, the lava outcrops at the edge of mesas, and drainages or streamsides are but a few. Others are roadsides, abandoned fields, burned areas, limestone outcrops, and the south and east slopes of Mt. Elden and Dry Lake Hills.

Each of these habitats has its own unique flora — along with certain species in common. Microhabitats occur where the community is influenced more by local conditions than the general climate. Some species can live only under these special circumstances. Other take advantage of special conditions to live outside of their normal range. These local variations may be very restricted in area (i.e., around a spring or on a boulder in the woods) or may be slightly larger (a sinkhole, for example).

The Rio de Flag Canyon at the front entrance to the museum is a good place to begin a search for spring wildflowers. With its tributaries and springs, lava outcrops, and pine forest, this canyon supports one of the richest floras in the area.

The Forest

In late March, Wild Candytuft, a definite harbinger of spring, pokes up between mud and remnant snow patches in the Ponderosa Pine forest. One of the earliest spring denizens, its white, four-petaled flowers appear at the top of the stalks — giving a clustered, tufted appearance to the plants.

Wood Betony and Northern Fairy Candelabra also appear in the pine forest's herb layer shortly after the snow melts. The Wood Betony has irregularly-shaped flowers, whitish at the base with purple tips, and finely dissected leaves. The small Northern Fairy Candelabra is very suitably named, for its clusters of delicate white flowers resemble miniature starbursts.

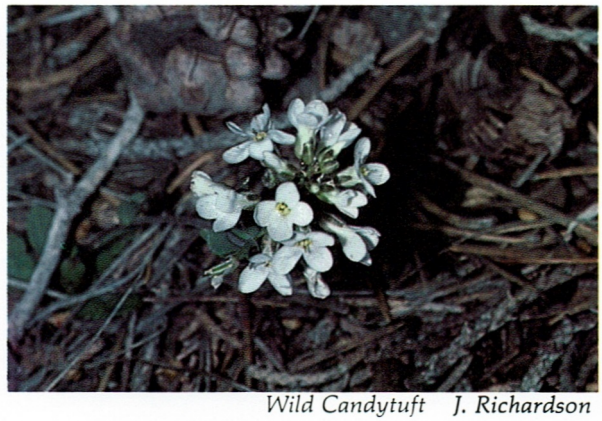
By April, Wax Currant, a small shrub with white or pink tubular flowers that frequently grows at the base of pine stumps or near fallen logs, is in bloom. The graceful Serviceberry, which looks like a small apple tree with its white, rosaceous blooms, is also present although it is less common. In June, it supplies tiny, bluish, apple-like fruits relished by birds and other animals. Not much taller than the lichens and mosses that grow underfoot, Pussytoes spreads as a prostrate mat of silvery leaves close to the forest ground, yet its fuzzy flowers in May tell us that it is related to the giant Sunflower.

The Mesas

In late March, most of the small herbs on the open mesa are still covered with snow, but the fall-flowering Rabbitbrush and Snakeweed shrubs and dark lava boulders have bare patches of ground

Oldman Whiskers J. Richardson

Purple Locoweed E. Balzer



Wild Candytuft J. Richardson

Yellow Monkeyflower A. Clay

Sego Lily E. Balzer

Wood Betony J. Richardson

Pussytoes J. Richardson

Serviceberry J. Richardson

Banana Yucca A. Phillips

Yellow Deervetch E. Balzer

Wild Iris J. Richardson

Watercress J. Richardson

Sulfurflower J. Richardson

Butterflyweed B. Phillips

Goatsbeard J. Richardson

Mountain Dandelion J. Richardson

A great diversity of spring wildflowers can be found in the Flagstaff area. Meadows, mesas, the pine forests, and a wide variety of microhabitats contribute to this diversity.

Pinedrops J. Richardson

Coralroot J. Richardson

Houstonia B. Phillips

Lobe-leaf Groundsel J. Richardson

Fremont Barberry J. Richardson

around them. Most flowering here occurs in mid-to-late May.

Rivulets of water from the melting snow coalesce into small streams, and grasses often grow in tufts lodged between the rocks of these drainages. Since the mesa is very rocky and soil development is poor, the soil usually remains waterlogged into late spring, providing abundant moisture for plants. In the slightly drier areas, Oldman Whiskers, with its pinkish flowers and fernlike leaves, is a common sight. By May, the long, gray, fuzzy tails of the fruits that give this plant its common name will protrude from the nodding reddish heads.

By mid-May, the mesa presents a dazzling display. Cream-colored Sego Lilies, yellow and orange Mountain Dandelions, red and yellow Indian Paintbrush, Sulfur Flowers (a wild buckwheat), and yellow-flowered Goatsbeard are some of the colorful flowers. Blue-flowered Lupines and bright yellow Butter and Eggs, common on the mesa, are still vegetative at this time.

The tiny Fragile Prickly Pear Cactus has joints with sharp, barbed spines that attach themselves to anything or anyone passing by. This form of vegetative propagation, though a nuisance to those forced to participate, is an efficient way to disperse the plants.

Gambel Oaks growing at the edge of the mesas leaf out in mid-May — about the time the first flowers appear on the large mounds of Claret Cup Cactus. The brilliant red flowers of this hedgehog brighten the rock crevices where it is lodged. With up to several hundred stems, it is similar to the Arizona Beehive Cactus. However, the latter has shorter spines, and its flowers are magenta.

The tiny clusters of yellow flowers on the Squawbush emerge before its leaves. The red, sticky, and hairy berries of this species, a tall shrub closely related to Poison Ivy, are eaten by birds and small mammals; larger mammals eat its bark and foliage.

Rock Spiraea grows among the huge lava boulders forming the outcrop above the meadow. This small shrub with peeling gray bark is a fairly rare plant in the area. In June, a feathery spray of showy, creamy-white flowers appears at the ends of the branches — followed by long-tailed fruit similar to those of Oldman Whiskers.

The Meadows

Many natural meadows in the Flagstaff area are filled valleys with deep soil. These open areas support a large number of sun-loving wildflowers.

In the flooded basins, Wild Iris, Yellow Evening Primrose, and Cinquefoil make their appearance in May. The delicate spears of Wild Iris seem to elongate inches each day. The pale blue to violet flags are similar to but smaller than the cultivated Iris. When present in large patches (connected by underground rhizomes), they present an attractive display. The four, large, paper-thin petals of the Yellow Evening Primrose briefly reflect the morning dew. Unlike their white-flowered relatives that open their flowers in the evening to attract night-flying moths as pollinators, these yellow flowers open at sunrise and usually last less than a day. The small, yellow flowers of the herbaceous Cinquefoil are similar to the larger, roselike flowers of the Shrubby Cinquefoil found in Hart Prairie.

The absence of pine trees in natural meadows is probably caused by a combination of several factors. The high soil moisture in spring (followed by drought and high soil surface temperatures in late June) kills many seeds. If the remaining seeds manage to germinate during the rainy season of July and August, the young tree seedlings must compete with native grasses such as Arizona Fescue, which use up the available water in the upper foot of soil. The seedlings must then survive browsing by deer and rabbits. If they do not rot in the moisture-laden soils as the snow melts the next spring, they must again survive the June drought.

The Inversion Zone

A temperature inversion zone occurs on the steep south and east slopes of Dry Lake Hills and Mt. Elden. Many plants normally found one thousand feet below the Ponderosa Pine zone grow up to one thousand feet above the pines, where Douglas Fir and Limber Pine would be expected. Instead of temperatures decreasing as elevation increases, they grow warmer until the top of the inversion is reached about midway up the slope. Nighttime temperatures are between five and forty degrees warmer in this habitat than in Flagstaff or Fort Valley. The steep south and east slopes with thin soil and the exposed, heat-retaining bulk of volcanic rock accentuate this phenomenon — creating a thermal zone, the "citrus belt" of Flagstaff.

Within the inversion area, exceptionally large Alligator-bark Juniper (at the northern end of its range), Pinyon Pine, and Gambel Oak as well as many shrubs and succulents such as Banana Yucca and cacti replace the Ponderosa Pines in dominance.

Claret Cup Cactus E. Balzer

Yellow Evening Primrose J. Richardson

Checker Mallow B. Phillips

Hairy Fleabane J. Richardson

Cliffrose J. Richardson

Shrubby Cinquefoil B. Phillips

The vegetation is denser and scratchier than in the forest. A species of Barberry with tough, spiny leaves; small, yellow flowers; and purple berries eaten by wildlife occurs here. Fremont Barberry frequently grows to be nine feet tall.

The beautiful, cream-colored flowers of Cliffrose bloom from June through October, emitting a sweet fragrance. This large, upright shrub is a favored winter browse for deer. Although the small, rose-colored flowers of Littleleaf Mountain Mahogany are not as showy as Cliffrose, the fruits of this member of the Rose family also develop long, feathery tails. Like Cliffrose, it is browsed by deer. The nearby Buckbrush, a low, spiny bush covered with clusters of small, white flowers, records the same use in its name.

The Roadsides

By late June, the species blooming in the pine forest and along the roadside are those that will continue to flower into the summer. Blue Lupine, Purple Locoweed, Purple Vetch, Yellow Deervetch, and Sweet Clovers (yellow first followed by white in about two weeks) are some of the legumes. Also flowering are Hairy Fleabane, the yellow-flowered Lobe-leaf Groundsel, and Bitterweed, members of the Sunflower family. Although the foot-tall Butterflyweed produces typical milkweed flowers and pods, its sap is clear rather than milky. Around Flagstaff, the flowers of this species are yellow instead of the more common dark orange. Near Schultz Creek, the Arizona Rose is in full bloom. This is the common species of wild Rose in Arizona, found along streams and in the Ponderosa forest.

Coyote Spring

Arroyo Willows line the creek to the lava ridge above Coyote Spring, near the museum's research center. Coralroot, a tiny orchid with crimson-purple to greenish and white flowers, grows on this rocky outcrop. Its brown-purple stems and minute leaves reflect the fact that the plant does not manufacture its own food but is a parasite on a mycorrhizal fungus. The nearby Pinedrops also lacks chlorophyll — obtaining its food from decaying wood or leaf mold. The latter plants are glandular (sticky-clammy to the touch) and have reddish, flowering stalks with nodding flowers.

Although Coyote Spring has been developed with a springbox, there is enough discharge to provide a small riparian area. In June, Wild Iris and Checker Mallow are blooming among the grasses, rushes, and sedges while Yellow Monkeyflower and white-flowered Watercress are growing right in the water.

Checker Mallow is easy to recognize because its mauve to rose-purple flowers and its seeds are similar to the cultivated Hollyhock. Yellow Monkeyflower is aptly named since its yellow flowers with red spots resemble a monkey face. This species, found in small streams and springs, is widely distributed both elevationally and geographically in the West. Watercress is even more cosmopolitan. A native of western Europe, it is widely naturalized in North America along streams, in springs, and at the edges of shallow ponds.

It is interesting to note that species found in springs are often quite widespread in their distribution, the requirement for perennial water being the most important prerequisite for their presence. Ecological factors such as competition with other plant species, pollinator availability, herbivore interactions, and chance dispersal of seeds affect their distribution and establishment.

Conclusion

If measured by its wildflowers, spring in northern Arizona lasts from late February or early March in the deserts along the Colorado River to June in the high, forested mountains. As the season progresses, flowering seems to march uphill, with each area having its week or two of peak flowering only to yield to the next higher hill, plateau, or mountainside. The impressive diversity of wildflowers in northern Arizona reflects its varied topography and its central location among desert, plateau, and mountain areas of the Southwest — all of which have contributed to the richness of the flora.

Each spring, herbaceous perennials, woody shrubs, and even the area's trees provide colorful flowers. Spring annuals also make their appearance. However, it is only during those rare years that come perhaps once in a decade, or even a lifetime, that the deserts burst into spectacular beauty. Understanding why plants grow in specific habitats and what influences their flowering can lead to a much greater appreciation of all plants, whether common or rare.

Butter and Eggs J. Richardson

Lupine J. Richardson

Spring Wildflowers

Common Name	Scientific Name	Family
Alligator-bark Juniper	*Juniperus deppeana*	Cupressaceae
Amsonia	*Amsonia tomentosa* var. *stenophylla*	Apocynaceae
Apache-plume	*Fallugia paradoxa*	Rosaceae
Arizona Alder	*Alnus oblongifolia*	Betulaceae
Arizona Beehive Cactus	*Coryphantha vivipara* var. *arizonica*	Cactaceae
Arizona Bugbane	*Cimicifuga arizonica*	Ranunculaceae
Arizona Fescue	*Festuca arizonica*	Gramineae
Arizona Rose	*Rosa arizonica*	Rosaceae
Arizona Walnut	*Juglans major*	Juglandaceae
Arroyo Willow	*Salix lasiolepis*	Salicaceae
Banana Yucca	*Yucca baccata*	Agavaceae
Beardtongue	*Penstemon* spp.	Scrophulariaceae
Beath Milkvetch	*Astragalus beathii*	Leguminosae
Beavertail Cactus	*Opuntia basilaris*	Cactaceae
Birch-leaf Buckthorn	*Rhamnus betulaefolia*	Rhamnaceae
Bitterweed	*Hymenoxys bigelovii*	Compositae
Blackbrush	*Coleogyne ramosissima*	Rosaceae
Bladderpod	*Lesquerella gordoni*	Cruciferae
Brady Plains Cactus	*Pediocactus bradyi*	Cactaceae
Brittlebush	*Encelia farinosa*	Compositae
Buckbrush	*Ceanothus fendleri*	Rhamnaceae
Butter and Eggs	*Linaria dalmatica*	Scrophulariaceae
Butterflyweed	*Asclepias tuberosa*	Asclepiadaceae
California Barrel Cactus	*Ferocactus acanthodes*	Cactaceae
Checker Mallow	*Sidalcea neomexicana*	Malvaceae
Cinquefoil	*Potentilla* spp.	Rosaceae
Claret Cup Cactus	*Echinocereus*	Cactaceae
Cliffrose	*Cowania mexicana*	Rosaceae
Coralroot	*Corallorhiza maculata*	Orchidaceae
Cottonwood	*Populus fremontii*	Salicaceae
Creosotebush	*Larrea divaricata* ssp. *tridentata*	Zygophyllaceae
Crimson Monkeyflower	*Mimulus cardinalis*	Scrophulariaceae
Desert Columbine	*Aquilegia desertorum*	Ranunculaceae

Common Name	Scientific Name	Family
Desert Dandelion	*Malacothrix glabrata*	Compositae
Desert Pepperweed	*Lepidium fremontii*	Cruciferae
Douglas Fir	*Pseudotsuga menziesii*	Pinaceae
Evening Primrose (annual)	*Camissonia exilis*	Onagraceae
Evening Primrose	*Oenothera pallida*	Onagraceae
Fragile Prickly Pear Cactus	*Opuntia fragilis*	Cactaceae
Fremont Barberry	*Berberis fremontii*	Berberidaceae
Gambel Oak	*Quercus gambelii*	Fagaceae
Goatsbeard	*Tragopogon dubius*	Compositae
Golden Columbine	*Aquilegia chrysantha*	Ranunculaceae
Goldenweed	*Machaeranthera pinnatifida*	Compositae
Grama Grass Cactus	*Pediocactus papyracanthus*	Cactaceae
Grand Canyon Scorpionweed	*Phacelia glechomaefolia*	Hydrophyllaceae
Grassleaf Peavine	*Lathyrus graminifolius*	Leguminosae
Grizzly Bear Cactus	*Opuntia erinacea*	Cactaceae
Hairy Fleabane	*Erigeron concinnus*	Compositae
Hedgehog Cactus	*Echinocereus* spp.	Cactaceae
Helleborine Orchid	*Epipactis gigantea*	Orchidaceae
Hiddenflower	*Cryptantha* spp.	Boraginaceae
Hollyhock	*Althea rosea*	Malvaceae
Houstonia	*Houstonia wrightii*	Rubiaceae
Indian Paintbrush	*Castilleja* spp.	Scrophulariaceae
Limber Pine	*Pinus flexilis*	Pinaceae
Littleleaf Mountain Mahogany	*Cercocarpus montanus*	Rosaceae
Lobe-leaf Groundsel	*Senecio multilobatus*	Compositae
Lupine	*Lupinus* spp.	Leguminosae
Maidenhair Fern	*Adiantum capillus-veneris*	Adiantaceae
Mexican Poppy	*Eschscholzia californica* ssp. *mexicana*	Papaveraceae
Mohave Aster	*Xylorhiza tortifolia*	Compositae
Mormon Tea	*Ephedra nevadensis*	Ephedraceae
Mountain Dandelion	*Agoseris* spp.	Compositae
Narrowleaf Yucca	*Yucca angustifolia*	Agavaceae
Navajo Plains Cactus	*Pediocactus peeblesianus* var. *peeblesianus*	Cactaceae
Netleaf Hackberry	*Celtis reticulata*	Ulmaceae
Northern Fairy Candelabra	*Androsace septentrionalis*	Primulaceae
Ocotillo	*Fouquieria splendens*	Fouquieriaceae
Oldman Whiskers	*Geum triflorum*	Rosaceae
Palmer Beardtongue	*Penstemon palmeri*	Scrophulariaceae
Pepperweed	*Lepidium fremontii*	Cruciferae
Perennial Rockcress	*Arabis perennans*	Cruciferae
Pinedrops	*Pterospora andromedea*	Ericaceae
Pinyon Pine	*Pinus edulis*	Pinaceae
Poison Ivy	*Toxicodendron rydbergii*	Anacardiaceae
Ponderosa Pine	*Pinus ponderosa*	Pinaceae
Purple Bladderpod	*Lesquerella purpurea*	Cruciferae
Purple Locoweed	*Oxytropis lambertii*	Leguminosae
Purple Sage	*Salvia dorrii*	Labiatae
Purple Vetch	*Vicia americana*	Leguminosae
Pussytoes	*Antennaria* spp.	Compositae
Rabbitbrush	*Chrysothamnus nauseosus*	Compositae
Red Osier Dogwood	*Cornus stolonifera*	Cornaceae
Rock Spiraea	*Holodiscus dumosus*	Rosaceae
Sacred Datura	*Datura meteloides*	Solanaceae
Sagebrush	*Artemisia tridentata*	Compositae
San Francisco Peaks Groundsel	*Senecio franciscanus*	Compositae
Scorpionweed	*Phacelia* spp.	Hydrophyllaceae
Sego Lily	*Calochortus nuttallii*	Liliaceae
Serviceberry	*Amelanchier utahensis*	Rosaceae
Shrubby Cinquefoil	*Potentilla fruticosa*	Rosaceae
Snakeweed	*Gutierrezia sarothrae*	Compositae
Squawbush	*Rhus trilobata*	Anacardiaceae
Streptanthella	*Streptanthella longirostris*	Cruciferae
Sulfurflower	*Eriogonum umbellatum*	Polygonaceae
Sunflower	*Helianthus annuus*	Compositae
Sweet Clover	*Melilotus* spp.	Leguminosae
Teddy Bear Cholla	*Opuntia bigelovii*	Cactaceae
Twining Snapdragon	*Maurandya antirrhiniflora*	Scrophulariaceae
Utah Penstemon	*Penstemon utahensis*	Scrophulariaceae
Velvet Ash	*Fraxinus pennsylvanica* ssp. *velutina*	Oleaceae
Watercress	*Nasturtium officinale*	Cruciferae
Wax Currant	*Ribes cereum*	Saxifragaceae
Weakstem Mariposa Lily	*Calochortus flexuosus*	Liliaceae
Western Redbud	*Cercis occidentalis*	Leguminosae
White Bursage	*Ambrosia dumosa*	Compositae
White Evening Primrose	*Oenothera pallida*	Onagraceae
Wild Candytuft	*Thlaspi montanum* var. *fendleri*	Cruciferae
Wild Iris	*Iris missouriensis*	Iridaceae
Wood Betony	*Pedicularis centranthera*	Scrophulariaceae
Yellow Deervetch	*Lotus wrightii*	Leguminosae
Yellow Evening Primrose	*Oenothera flava*	Onagraceae
Yellow Monkeyflower	*Mimulus guttatus*	Scrophulariaceae

SUGGESTED READINGS

Arnberger, L. P. 1982. Flowers of the Southwest Mountains. Southwest Parks and Monuments Association, Globe, Arizona. 139 p.

Bell, K. L., H. D. Hiatt, and W. E. Niles. 1979. "Seasonal Changes in Biomass Allocation in Eight Winter Annuals of the Mojave Desert." *Journal of Ecology* 67:781-787.

Benson, L. 1969. The Cacti of Arizona. 3rd. ed., University of Arizona Press, Tucson, Arizona. 218 + xvii p.

Burk, J. H. 1982. "Phenology, Germination, and Survival of Desert Ephemerals in Deep Canyon, Riverside County, California." *Madrono* 29:154-163.

Juhren, M., F. W. Went, and E. Phillips. 1956. "Ecology of Desert Plants. IV. Combined Field and Laboratory Work on Germination of Annuals in the Joshua Tree National Monument, California," *Ecology* 37:318-330.

McDougall, W. B. 1957. "Botany of the Museum and Colton Ranch Area." I. General botany. *Plateau* 29:81-87.

McDougall, W. B. 1964. Grand Canyon Wild Flowers. Museum of Northern Arizona, Flagstaff, Arizona and Grand Canyon Natural History Association, Grand Canyon, Arizona. 259 + ix p.

McDougall, W. B. 1973. Seed Plants of Northern Arizona. Museum of Northern Arizona, Flagstaff, Arizona. 594 p.

McDougall, W. B., and H. S. Haskell. 1959. Typical Seed Plants of the Ponderosa Pine Zone. Museum of Northern Arizona, Flagstaff, Arizona. *Bulletin* 32. 63 p.

Phillips, A. M., III. 1975. "Flora of the Rampart Cave Area, Lower Grand Canyon, Arizona." *Journal Arizona Academy Science* 10:148-159.

Phillips, Arthur M., III. 1977. "Grand Canyon Biology: A Botanist's View." *Plateau* 49(4):11-17.

Phillips, A. M., III. 1979. Grand Canyon Wildflowers. Grand Canyon Natural History Association, Grand Canyon, Arizona. 145 p.

Phillips, A. M., III, and B. G. Phillips. 1980. "Vegetation and Flora of Grand Canyon National Park, Arizona." Proc. of the 2nd Conference on Research in National Parks. National Park Service, Washington, D.C.

Phillips, B. G., and A. M. Phillips, III. 1974. "Spring Wildflowers of the Inner Gorge, Grand Canyon, Arizona." *Plateau* 46:149-157.

Tevis, L., Jr. 1958. "Germination and Growth of Ephemerals Induced by Sprinkling a Sandy Desert." *Ecology* 39:681-688.

Tevis, L., Jr. 1958. "A Population of Desert Ephemerals Germinated by Less than One Inch of Rain." *Ecology* 39:688-695.

Went, F. W. 1948. "Ecology of Desert Plants. I. Observations on Germination in the Joshua Tree National Monument, California." *Ecology* 29:242-253.

Went, F. W. 1949. "Ecology of Desert Plants. II. The Effect of Rain and Temperature on Germination and Growth." *Ecology* 30:1-13.

Went, F. W. 1955. "The Ecology of Desert Plants." *Scientific American* 192:68-75.

Williams, R. B., and K. L. Bell. 1981. "Nitrogen Allocation in Mojave Desert Winter Annuals." *Oecologia* 48:145-150.

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